

Claims

- 5 1. A method for the heat treatment of solids containing titanium, in which fine-grained solids are treated at a temperature of 700 to approximately 950°C in a fluidized bed reactor (1), **characterized in that** a first gas or gas mixture is introduced from below through at least one preferably central gas supply tube (3) into a mixing chamber (7) of the reactor (1), the gas supply tube (3) being at
10 least partly surrounded by a stationary annular fluidized bed (10) which is fluidized by supplying fluidizing gas, and that the gas velocities of the first gas or gas mixture as well as of the fluidizing gas for the annular fluidized bed (10) are adjusted such that the particle Froude numbers in the gas supply tube (3) are between 1 and 100, in the annular fluidized bed (10) between 0.02 and 2 and in
15 the mixing chamber (7) between 0.3 and 30.
2. The method as claimed in claim 1, **characterized in that** the particle Froude number in the gas supply tube (3) lies between 1.15 and 20, in particular is approximately 12 to 15.
- 20 3. The method as claimed in claim 1 or 2, **characterized in that** the particle Froude number in the annular fluidized bed (10) is between 0.115 and 1.15, in particular approximately 0.2 to 0.4.
- 25 4. The method as claimed in one of the preceding claims, **characterized in that** the particle Froude number in the mixing chamber (7) is between 0.37 and 3.7, in particular approximately 1.4.
- 30 5. The method as claimed in one of the preceding claims, **characterized in that** the bed height of solids in the reactor (1) is adjusted such that the annular

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fluidized bed (10) extends at least partly beyond the upper orifice end of the gas supply tube (3) and that solids are constantly introduced into the first gas or gas mixture and entrained by the gas stream to the mixing chamber (7) located above the orifice region of the gas supply tube (3).

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6. The method as claimed in any of the preceding claims, **characterized in that** the first gas or gas mixture is passed through a gas supply tube (3) provided with apertures on its shell surface, for example in the form of slots.

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7. The method as claimed in any of the preceding claims, **characterized in that** ilmenite is used as the starting material and is reduced in the reactor (1).

8. The method as claimed in any of the preceding claims, **characterized in that** hydrogen-containing gas is supplied to the reactor (1).

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9. The method as claimed in claim 8, **characterized in that** hydrogen-containing gas with a hydrogen content of 75 to 100%, in particular of 85 to 95%, is introduced into the reactor (1) through the gas supply tube (3) and/or into the annular fluidized bed (10).

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10. The method as claimed in claim 8 or 9, **characterized in that** the hydrogen-containing gas contains between 0 and 5%, in particular between 0.3 and 4.0%, of water vapour and between 5 and 10%, in particular between 7 and 8%, of nitrogen.

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11. The method as claimed in any of claims 8 to 10, **characterized in that** the hydrogen-containing gas is introduced into the reactor (1) with a temperature of between 820 and 900°C, in particular between 840 and 880°C.

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12. The method as claimed in any of the preceding claims, **characterized in that** at least part of the exhaust gas of a second reactor (13), provided downstream of the reactor (1), is passed through the gas supply tube (3) into the reactor (1).

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13. The method as claimed in any of the preceding claims, **characterized in that** the amount of iron contained in the solids is reduced in the reactor (1) to at least 70%, in particular to approximately 80%.

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14. The method as claimed in either of claims 12 and 13, **characterized in that** the amount of iron contained in the solids is reduced in the downstream second reactor (13) to at least 90%, in particular approximately 97%.

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15. The method as claimed in any of the preceding claims, **characterized in that**, following re-processing by separation of the solids, cooling and separation of the water, at least part of the exhaust gas of the reactor (1) is heated up and supplied to the annular fluidized bed (10) of the reactor (1) through the conduit (6).

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16. The method as claimed in any of the preceding claims, **characterized in that** a cooling stage (20) for the solids is provided downstream of the second reactor (13).

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17. The method as claimed in any of claims 12 to 16, **characterized in that** a separating stage (9, 17) for separating the solids from the exhaust gas is respectively provided downstream of the reactor (1) and of the downstream second reactor (13), and that the separated solids are at least partly supplied to the respective stationary fluidized beds (10) of the reactors (1, 13).

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18. The method as claimed in one of claims 1 to 6, **characterized in that** ilmenite is used as the starting material and is magnetically roasted in the reactor (1).

5 19. The method as claimed in claim 18, **characterized in that** fuel which, by its combustion with an oxygen-containing gas, generates at least part of the amount of heat required for the thermal treatment is supplied to the reactor (1).

10 20. The method as claimed in either of claims 18 and 19, **characterized in that** gaseous fuel, preferably natural gas, is introduced through lances (37) or the like into the mixing chamber (7), the annular fluidized bed (10) and/or through a conduit (35) into the gas supply tube (3) and from there together with oxygen-containing gas into the reactor (1), and that compressed ambient air or pre-heated air is introduced as fluidizing gas via a supply conduit (6) and a gas
15 distributor (5) into the annular fluidized bed (10) of the reactor (1).

21. The method as claimed in any of claims 18 to 20, **characterized in that** air, which is pre-heated, in particular in a cooling stage (31, 32) provided downstream of the reactor (1), and possibly dust-laden, is introduced into the reactor
20 (1) through the gas supply tube (3).

22. The method as claimed in any of claims 18 to 21, **characterized in that** solids are removed from the reactor (1) from the annular fluidized bed (10) and supplied to a cooling stage (31, 32), in particular to a suspension heat exchanger (31), in which the solids are subjected to a cooling medium, such as air,
25 and to a downstream separator, for example a cyclone (32).

23. The method as claimed in any of claims 18 to 22, **characterized in that** at least part of the exhaust gas of the reactor (1) is largely separated from solids
30 in a downstream separator, in particular a cyclone (9), and supplied to a pre-

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heating stage upstream of the reactor (1) with a dryer, for example a venturi dryer (29), and a separator, for example a cyclone (30), for drying and pre-heating the solids to be supplied to the reactor (1).

5 24. The method as claimed in claim 23, **characterized in that** the solids separated from the exhaust gas in the separator (9) provided downstream of the reactor (1) are supplied to the annular fluidized bed (10) and/or the suspension heat exchanger (31).

10 25. The method as claimed in any of claims 18 to 24, **characterized in that** the solids removed from the reactor (1) are supplied after a first cooling stage (31) or directly to a further cooling stage, which has a fluidized injection cooler (38) and/or fluidized bed cooler (41, 42).

15 26. The method as claimed in claim 25, **characterized in that** the solids are cooled to below 300°C, in particular to below 200°C, in the injection cooler (38) by injecting water and are cooled to the further processing temperature in the fluidized bed coolers (41, 42) by water passed in counter-current through cooling coils.

20 27. The method as claimed in claim 25 or 26, **characterized in that** the exhaust gas of the further cooling stage (38, 41, 42) and of the separator (30) of the pre-heating stage is supplied to a further separator, in particular a bag filter (46), and that the solids separated in the further separator (46) are supplied to
25 one of the fluidized bed coolers (41, 42).

28. A plant for the heat treatment of solids containing titanium, in particular for performing a method as claimed in one of claims 1 to 27, comprising a reactor (1) constituting a fluidized bed reactor, **characterized in that** the reactor (1)
30 has a gas supply system which is formed such that gas flowing through the gas

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supply system entrains solids from a stationary annular fluidized bed (10), which at least partly surrounds the gas supply system, into the mixing chamber (7).

29. The plant as claimed in claim 28, **characterized in that** the gas supply system has at least one gas supply tube (3) extending upwards substantially vertically from the lower region of the reactor (1) into a mixing chamber (7) of the reactor (1), the gas supply tube (3) being at least partly surrounded by an annular chamber in which the stationary annular fluidized bed (10) is formed.

30. The plant as claimed in claim 29, **characterized in that** the gas supply tube (3) is arranged approximately centrally with reference to the cross-sectional area of the reactor (1).

31. The plant as claimed in claim 29 or 30, **characterized in that** provided in the annular chamber of the reactor (1) is a gas distributor (5) which divides the chamber into an upper fluidized bed region (10) and a lower gas distributor chamber (4), and that the gas distributor chamber (4) is connected to a supply conduit (6) for in particular heated-up hydrogen-containing or fuel-containing fluidizing gas.

32. The plant as claimed in any of claims 29 to 31, **characterized in that** a solids separator, in particular a cyclone (9), is provided downstream of the reactor (1) for separating solids, and that the solids separator has a solids conduit (14) leading to the annular fluidized bed (10) of the reactor (1) and/or to the stationary fluidized bed of a second reactor (13) possibly provided downstream.

33. The plant as claimed in either of claims 31 and 32, **characterized in that** a re-processing stage (23, 24, 25, 26, 27, 28) for the exhaust gas is provided downstream of the solids separator (9) of the reactor (1).

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34. The plant as claimed in either of claims 32 and 33, **characterized in that** the second reactor (13) likewise has a downstream solids separator (17), the exhaust gas of which is passed via a supply conduit (21) into the fluidized bed (10) of the first reactor (1).

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35. The plant as claimed in any of claims 28 to 32, **characterized in that** the reactor (1) has a conduit (35) leading to the gas supply tube (3) and/or to a supply conduit for in particular gaseous fuel, leading to a lance arrangement (37) which opens out into the annular fluidized bed (10).

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36. The plant as claimed in any of claims 28 to 32, **characterized in that** provided upstream of the reactor (1) is a pre-heating stage for the solids, the dryer (29) of which is connected to the exhaust-gas conduit of the separator (9) provided downstream of the reactor (1), and that a cooling stage (31, 32) provided downstream of the reactor (1) has an exhaust-gas conduit connected to the gas supply tube (3).

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37. The plant as claimed in claim 36, **characterized in that** at least one further cooling stage (38, 41, 42) is provided downstream of the reactor (1).